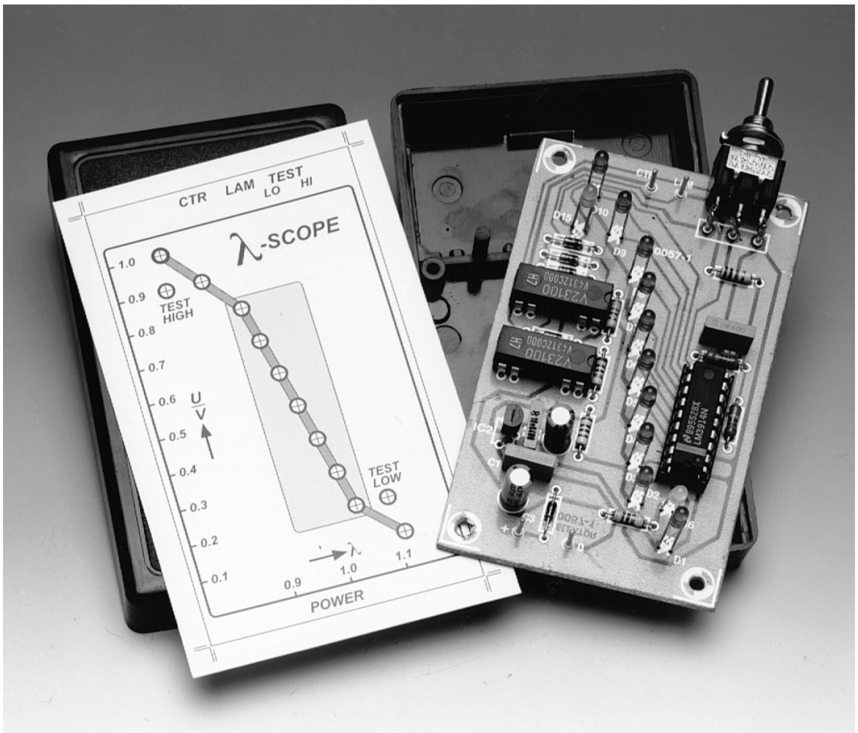
EGO sensor tester

ensuring a correct air-fuel ratio

One of the most important parameters in modern motor vehicle management is the air-fuel ratio, since this affects the ‘cleanliness’ or otherwise of the exhaust gases. In fact, the ratio is measured indirectly by the amount of oxygen in the exhaust gases. The sensor used for this is the exhaust gas oxygen (EGO) sensor. This is sometimes called a lambda sensor from the Greek letter lambda (λ) which denotes the equivalence ratio (ratio of actual air-fuel mixture to ideal air-fuel mixture). The correct operation of this sensor may be tested and monitored with the circuit described in this article.

Design by H. Bonekamp



Most modern engine control systems are digital and contain a number of microprocessors; in fact, they are essentially special-purpose computers. Their primary purpose is to regulate the air-fuel mixture, the ignition timing and and the exhaust gas recirculation (EGR).

The air-fuel ratio is important not only from an economic point of view, but also from an environmental one, since it affects the amount of harmful constituents in the exhaust gases. It is controlled by an engine control system that consists of a number of sensors (air flow; engine coolant; engine position; throttle position; exhaust gas oxygen; and others), a digital control unit, and various actuators (air-fuel ratio; ignition; exhaust gas recirculation – EGR).

One specific air-fuel ratio is crucial: the stoichiometric (chemically correct) mixture. This mixture corresponds to an air-and-fuel combination of which, if combustion were perfect, all the hydrogen and carbon would be converted by the burning process into harmless water (H_2O) and carbon dioxide (CO_2). The stoichiometric ratio for a petrol engine is 14.7:1. The ratio of the actual fuel-and-air mixture to the stoichiometric mixture is the equivalence ratio, represented by the Greek letter lambda (λ).

Unfortunately, combustion is not perfect: the exhaust gases also contain harmful carbon monoxide (CO), oxides of nitrogen (NO_x), unburned hydrocarbons (HC), oxides of sulphur, and others.

Government standards in all western countries require these harmful emissions to be reduced in stages by up to 100 per cent. The device most frequently used by vehicle manufacturers is a catalytic converter in the exhaust system. Exhaust gases passed through the converter are chemically altered to help meet these standards. The main functions of the converter are therefore to:

- oxidize hydrocarbon emissions to carbon dioxide (CO_2) and water (H_2O);

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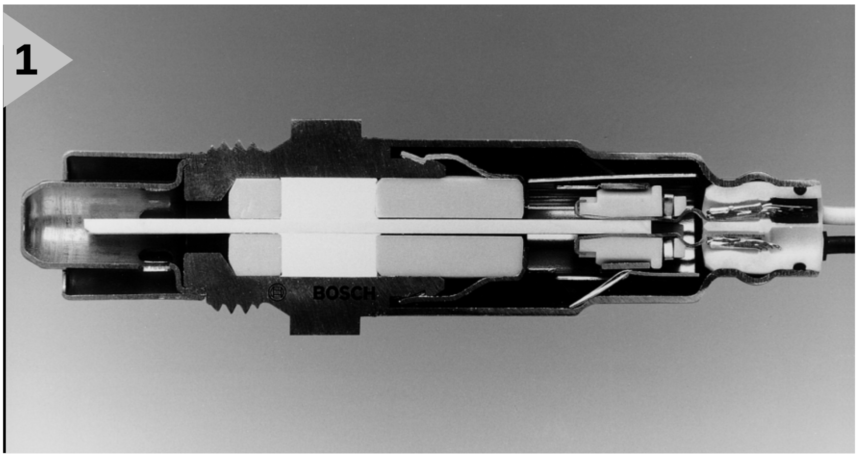

Figure 1. Typical planar, wide-band EGO sensor (Bosch).

- oxidize CO to CO_2;
- reduce NO_x to nitrogen (N_2) and oxygen (O_2).

The purpose of the oxidizing catalyst (OC) is to increase the rate of chemical reaction which initially takes place in the cylinder as the compressed air-fuel mixture burns, to an exhaust gas that has a complete oxidation of HC and CO to H_2O and CO_2.

The amount of oxygen in the exhaust gases is used as an indirect measurement of the air-fuel ratio. Consequently, one of the most important sensors in use in modern vehicles is the exhaust gas oxygen (EGO) sensor. This is sometimes called the lambda sensor since this Greek letter (λ) denotes the equivalence ratio mentioned earlier. The most commonly used EGO sensor is based on zirconium dioxide (ZrO_2); another one is based on titanium dioxide (TiO_2).

HEATED EGO SENSOR

The stringent exhaust emission requirements have made it necessary for the time from engine start to the point at which the EGO reaches operating temperature to be shortened. This has led to the development of the heated exhaust gas oxygen (HEGO) sensor. This is electrically heated from engine start until the sensor is active (at about 600 °C).

The HEGO sensor shown in **Figure 1** analyses the various constituents of the exhaust gases. The output of the sensor is fed back to the electronic control unit, which is then able to adjust the air-and-fuel mixture as required.

The sensor consist of a section of zirconium dioxide with thin platinum electrodes on the inside and outside of the ZrO_2. The inside electrode is exposed to air, and the outside electrode to exhaust gases through a porous protective coating.

The platinum plate at the air side is exposed to a much greater concentration of oxygen ions than the plate at the exhaust gas side. This results in the air-side plate becoming electrically more negative than the exhaust-side plate. Consequently there is an electric potential between the plates: positive at the exhaust gas side and negative on the air side. The level of this potential depends on the concentration of oxygen in the exhaust gases and on the sensor temperature.

NOT TOO LEAN; NOT TOO RICH

When the air-and-fuel mixture is stoichiometric (14.7:1), the equivalence ration, λ, is 1. When this ratio is <1, the mixture is rich, and when it is >1, the mixture is lean. At the stoichiometric mixture, the output of the EGO sensor alternates around 0.5 V; the frequency of alternation depends on the time constant of the control loop. A steady output of 0.5 V indicates that either the control loop is defect or the EGO sensor is inactive or cold.

When the sensor output is higher than 0.5 V, the mixture is too rich (not enough oxygen). This is only permissible when the engine is cold or under full-load conditions (in some makes of car the fuel-injection unit then enriches the mixture). In other circumstances, the fuel-injection unit and/or the engine temperature sensor should be tested.

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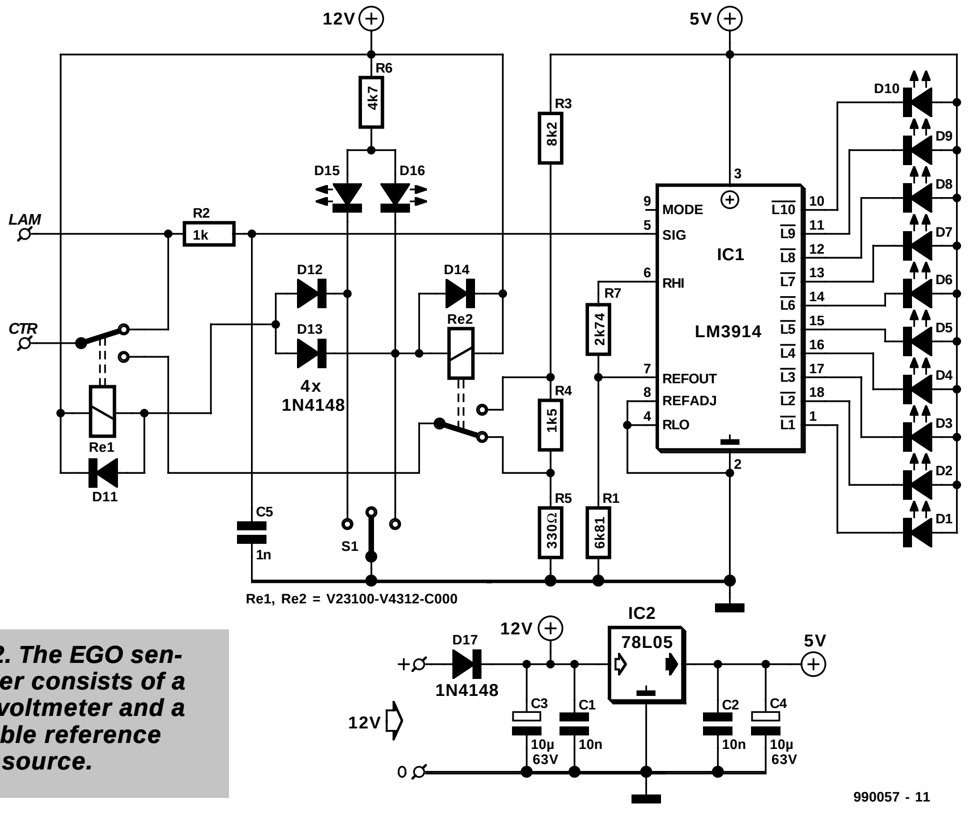

Figure 2. The EGO sensor tester consists of a kind of voltmeter and a switchable reference voltage source.

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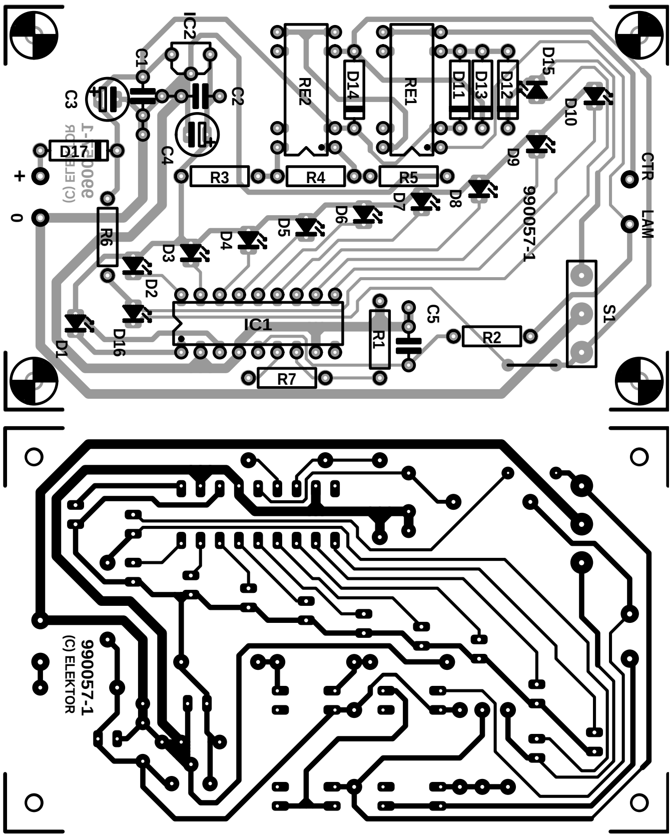

Figure 3. Printed-circuit board for the EGO sensor tester (not available ready made).

Parts list

Resistors:
R_1 = 6.81 kΩ
R_2 = 1 kΩ
R_3 = 8.2 kΩ
R_4 = 1.5 kΩ
R_5 = 330 Ω
R_6 = 4.7 kΩ
R_7 = 2.74 kΩ

Capacitors:
C_1, C_2 = 0.01 µF
C_3, C_4 = 10 µF, 63 V, radial
C_5 = 0.001 µF

Semiconductors:
D_1–D_{10} = LED, 3 mm, red, high efficiency
D_{11}–D_{14}, D_{17} = 1N4148
D_{15} = LED, 3 mm, yellow, high efficiency
D_{16} = LED, 3 mm, green, high efficiency

Integrated circuits:
IC_1 = LM3914
IC_2 = 78L05

Miscellaneous:
S_1 = 3-pole change-over switch with centre rest position for board mounting
Re_1, Re_2 = reed relay, 12 V coil with single change-over contact, Siemens V23100-V4312-C000

When the output of the sensor is <0.5 V, the mixture is too lean. This may be the case when the throttle is released at high engine revolutions. It is more likely, however, that there is insufficient fuel injected.

CIRCUIT OF PROPOSED TESTER

All that is needed for checking the correct operation of the EGO sensor is a kind of voltmeter as shown in **Figure 2**. Apart from terminals for inputting the supply voltage, the unit has terminals for connecting the output of the (H)EGO sensor (LAM) and the electronic engine controller (CTR).

The sensor output is applied to pin 5 (SIG) of LED-display driver IC_1. Network R_2-C_5 forms a low-pass filter that eliminates noise peaks on the signal line.

The reference voltage of IC_1 is set to such a value by R_1 and R_7 that the diodes cover a voltage window from 0 V (D_1) to 1 V (D_{10}) in 0.1 V steps. Diode D_5 represents the stoichiometric value (0.5 V).

The MODE pin (9) is open so that the display operates in the dot mode, which means that only one LED lights at any one time.

The cable in the vehicle between the electronic control unit and the sensor must, of course, be disconnected before the tester can be used. In some vehicles, it may be possible to cut this cable as appropriate and use one of the resulting lengths to connect the control unit to the tester, and the other to connect the tester to the sensor. This may, however, affect your rights under the terms of the vehicle warranty.

MONITORING & TESTING

Switch S_1 enables one of three modes of operation to be selected. When it is in the centre position as shown in the diagram, terminals LAM and CTR are interlinked, so that the control unit behaves as if the tester were not there. The tester then merely monitors the output voltage of the sensor, which is indicated by the LED display. It may remain connected when the vehicle is in use, but it should be borne in mind that this may invalidate guarantees and warranties.

In both other positions of the switch, the unit is in the test mode. The control unit is then no longer linked to the EGO sensor and the fuel injection is driven by a virtual high sensor output (test-hi) or a low one (test-lo). These virtual outputs are derived from potential divider R_3–R_5, the output of which is selected by the contact of relay Re_2. Diodes D_{15} and D_{16} indicate the selected test voltage (D_{15} in test-lo and D_{16} in test-hi).

The fuel injection actuator will optimize the air-fuel mixture: enrich it when the test voltage is low, and make it leaner when the test voltage is high.

The supply voltage regulation is traditional. Diode D_{17} prevents any damage to the electronic circuits when the supply lines are linked with incorrect polarity. The output is a clean and stable voltage at a level of 5 V. Note that the two relays are operated directly from the 12 V supply input.

CONTROL CHARACTERISTIC DISPLAYED

The display LEDs are placed on the printed-circuit board (not available ready made) for the EGO tester in the shape of a control curve. When only the diodes in the marked window at the centre of the display light it may be assumed that all is well. When diode D_1 lights, the air-fuel mixture is too lean; when D_9 or D_{10} lights, the mixture is too rich.

The diodes are placed along the control curve in such a way that the fuel injection control must correct the mixture to a value adjacent to the lit diode.

Completing the board and assembling the tester in a suitable case are straightforward. Circuit IC_1 and the two reed relays should be soldered directly to the board. The LEDs should not be soldered in place until it has been ascertained that they protrude slightly from the requisite holes in the enclosure.

The cables linking the tester to the sensor and to the control unit should be single screened types. The sensor output should be taken from a connector as close as possible to the sensor (which is mounted securely in the exhaust manifold). [990057]